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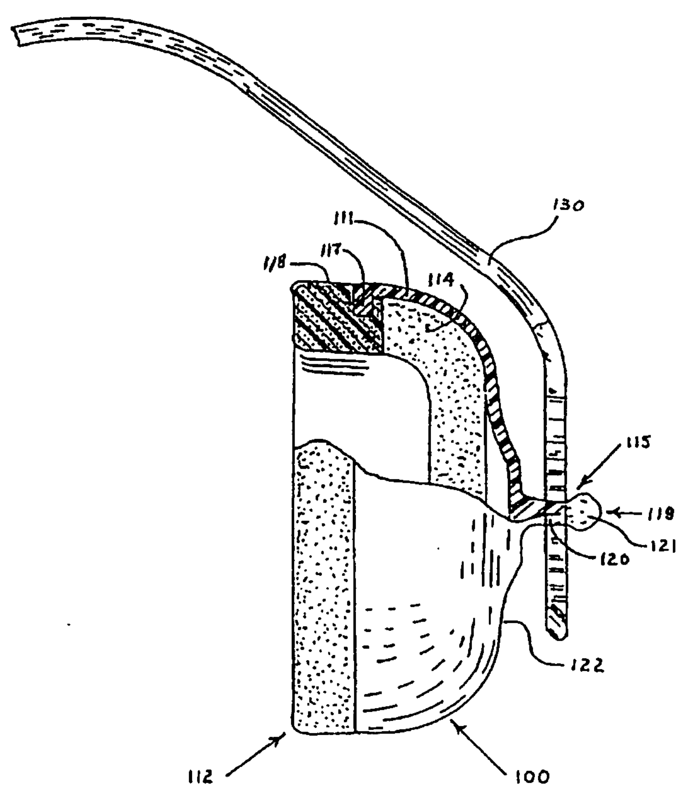
(57) Abstract

An acoustical earmuff device (100) is presented, incorporating a snap-in molded foam cushion (112) into an earmuff cup (122). The molded foam cushion (112) has an annular recess (118) adjacent the edge, matching a protrusion (117) near the edge of the earmuff cup (122), whereby the foam cushion may be snapped into the earmuff cup (122). Preferably, the cushion has a beveled or curved shape for optimal contact around the ear, an integrated sound-absorptive liner (114), and a stiffer interface layer to facilitate the cushion being snapped into the earmuff. The complete earmuff device of the present invnetion may have as few as three parts.



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ACOUSTICAL EARMUFF WITH INCORPORATED SNAP-IN FOAM CUSHION

Background of the Invention:

1. Field of the Invention

The present invention relates generally to acoustic ear protective devices and, more particularly, to an inexpensive, acoustical earmuff device with an incorporated foam cushion, which engages the earmuff cup in snap-in fashion.

2. Description of the Prior Art

The use of ear protection and noise attenuating devices is well known, and various types of devices are available for this purpose. One class of such devices, generally known as earmuffs, is comprised of a connecting member and a pair of muffs suitable for covering a wearer's ears. The muffs are suspended from opposite portions of the connecting member. Numerous earmuff designs have been developed to provide for improved hearing protection arrangements that are comfortable to wear for long periods of time, easy to maintain, and durable.

For example, referring to FIGURE 1, a typical set of acoustical earmuffs of the current art consists of two earmuffs (only one shown) 10 connected by a suitable means 15 to a flexible headband 13. Each earmuff 10 generally consists of a cup 16 and 17, a cushion 12 and a sound absorbing liner 14.

The cup is generally composed of a relatively stiff material such as rigid polyvinyl chloride, acrylonitrile butadiene styrene (ABS) or the like. It is usually composed of two pieces, the cup shaped portion 16 and the cushion sealplate 17, which have been ultrasonically sealed together at interface 21.

The sound absorbing liner 14 is an open cell foam or other material containing open pores of size and shape to absorb high frequency sound from about 2 KHz to 8 KHz. This material is a separate component which is normally die stamped from sheet and stuffed into the earmuff cup.

The cushion 12 is generally composed of a minimum of two thin sheets of flexible polyvinyl chloride or polyurethane, one of which is vacuum formed 18 and filled with a cut-out donut of foam 19 or a liquid, then thermally bonded to the second layer 20, after which the trim is cut off. This process is costly, labor-intensive, and results in considerable waste.

As shown by the above description, though appearing simple, earmuffs traditionally comprise many different parts requiring welding and other pre-assembly steps. In addition, a considerable amount of testing is necessary regarding the materials of construction, the band tension, the muff weight and volume, and the sound attenuation values. For example, in U.S. Patent No. 2,782,423, ear protectors are described having high frequency sound attenuation. The ear protectors utilize pads constructed of resilient, deformable isocyanate-plastic foam which absorb sound energy. The ear enclosing pads are preferably alike and each include an internal plate.

U.S. Patent No. 2,990,553 teaches an improved ear pad for use with noise protective devices that comprises tube-like sheaths of a plasticized plastic, each sheath being partially collapsed and completely filled with a mixture of paste-like consistency. In addition, liners of sound absorbing material, such as isocyanate foam, may be disposed within the earcup of the ear protective device.

U.S. Patent No. 4,437,538 discloses an ear-cap which is placed against the exterior of an ear. The ear-cap includes a cushion made of an elastic and porous material, the outside of the cushion being at least partially covered by a perforated disc. The disc defines a cavity which is closed beside the perforations. The ear-cap further

includes an earcup housing having a recessed portion partially defining a sound deadening cavity.

In U.S. Patent No. 4,658,931, a hearing protection arrangement is provided which employs the non-sound conductive properties of an evacuated chamber for attenuating sound energy reaching the user's ear.

Another typical earmuff assembly is disclosed in U.S. Patent No. 3,787,899 to Krawagna. It includes an earcup and a collar, the earcup being mounted in the collar for rotation about the first axis, extending normal to the earcup, a yoke to the collar, the collar being mounted in the yoke for rotation about a second axis which extends laterally of the first axis, the yoke being mountable on the headband. Further details concerning various headband-to-earcup constructions may be had by reference to U.S. Patent No. 3,719,954 to Beguine, U.S. Patent No. 3,908,200 to Lundin, and U.S. Patent No. 4,471,496 to Gardner, Jr.

While previous earmuffs have been suitable for many uses, they still possess certain drawbacks and disadvantages, one of these being that the devices consist of a multiplicity of parts. A multiplicity of parts leads to higher production and assembly costs. Although some of the previously patented hearing protection arrangements employ a cup-like structure and a suspension arrangement similar to that used in the present invention, none of these prior devices solves the problems associated with multi-part pre-assembly.

<u>Summary of the Invention:</u>

The above-discussed and other drawbacks and deficiencies of the prior art are overcome or alleviated by the acoustical earmuff device of the present invention, which incorporates a snap-in molded foam cushion having an integrated sound absorptive liner. It is to be understood that the term snap-in is used in a broad sense, and does not exclude use of an adhesive to further aid in attachment.

In a preferred embodiment of the present invention, the molded foam cushion includes a stiffer layer, which facilitates the cushion being snapped into the earmuff, while eliminating a cushion sealplate as a separate molded or produced element. In

addition, the molded foam cushion of the present invention preferably has an integral sound absorptive (acoustical) liner, which further reduces the number of components. The preferred shape of the molded foam cushion is beveled, having the most forward portion intended for contact with the wearer's head about the ear to be narrower than where the cushion contacts the earmuff cup. The tip of the bevel is on the inside of the foam cushion so as to seat the cushion closer to the wearer's ear. The preferred cushion material has a high dynamic stiffness, a spring constant of at least 300 pounds per inch (and most preferably 1000 pounds per inch), and a material loss factor of at least 0.25. These preferred elements result in a simpler manufacturing process with fewer manufacture and assembly steps, while retaining high performance at low frequency levels and enhanced comfort for the wearer.

In yet another alternative embodiment of the present invention, there is provided a foam-acoustical liner composite which may be incorporated into an earcup by adhesive or other means.

In the process of the present invention, there is provided a method for joining a sound absorptive (acoustical) liner to a molded cushion during the molding process. The open-celled acoustical liner facilitates venting from within the mold through the open-celled liner during molding. Upon contact of the rising foam cushion with the acoustical liner during the joining process, a stiffer interface layer may form. This stiffer interface layer aids in the snap-in and retention of the molded foam cushion into the earmuff cup.

The earmuff and process of this invention results in more positive cushion retention, as well as enhanced performance. In addition, three traditional earmuff parts, cushion, sealplate, and liner, are incorporated into a one-piece unitary structure. The molded cushions of this invention are easily removable and relatively inexpensive. Thus, the foam cushion inserts of the present invention are easily integrated with a pair of earcups and a connecting band to provide a user with cost effective, reusable, comfortable, and durable acoustic ear protective device for most environments requiring noise exclusion.

Brief Description of the Drawings:

FIGURE 1 is a schematic, diagrammatic, partially sectional, assembled front view of a prior art earmuff device.

FIGURE 2 is a schematic, diagrammatic, partially sectional, assembled front view of an earmuff device and incorporated foam cushion of the present invention.

FIGURE 3 is a schematic, diagrammatic, partially sectional, assembled front view of an earmuff device and preferred beveled incorporated foam cushion of the present invention.

FIGURE 4 is a rear view of a foam cushion of the present invention.

FIGURE 5 is a cross-section of line 3--3 of FIGURE 4.

FIGURE 6 is a perspective view of the earmuff device and incorporated foam cushion of the present invention.

FIGURE 7 is a rear view of a preferred foam cushion of the present invention.

FIGURE 8 is a cross-section of line 3--3 of FIGURE 6.

FIGURE 9 is a front view of the connecting band and earcup of the earmuff device with incorporated foam cushion of the present invention.

FIGURE 10 is a rear view of a foam cushion-acoustical liner composite of the present invention.

FIGURE 11 is a cross-section of line 3--3 of FIGURE 10.

FIGURE 12 is a rear view of a preferred foam cushion-acoustical liner composite of the present invention.

FIGURE 13 is a cross-section of line 3--3 of FIGURE 12.

FIGURE 14 is a rear view of a preferred foam cushion having a stiffer layer.

FIGURE 15 is a cross-section of line 3--3 of FIGURE 14.

FIGURE 16 is a rear view of a preferred foam cushion-acoustical liner composite having a stiffer layer of the present invention.

FIGURE 17 is a cross-section of line 3--3 of FIGURE 16.

FIGURES 18 through 27 are cross-sectional views of other contemplated molded foam cushion shapes and attachments to earmuff cups of the present invention.

FIGURE 28 is a view of the Transmissibility Test Fixture.

FIGURE 29 depicts the Transmissibility Test Equipment in block diagram form.

FIGURE 30 is a top view of a mold for the manufacture of a foam cushion-acoustical liner composite of the present invention.

FIGURE 31 is a cross-section of line 3--3 of FIGURE 30.

FIGURE 31A is a cross-section of a mold for the manufacture of a unitary earmuff cup and foam cushion-acoustical liner composite of the present invention.

FIGURE 32 are Transmissibility tracings for Example 1 and Example 2 cushions.

Description of the Preferred Embodiments:

Referring now to FIGURES 2 and 6, the earmuff device with incorporated foam cushion of the present invention broadly comprises a generally U-shaped, resilient connecting band 130 and an acoustic earmuff 100. The earmuff 100 is attached to the connecting band 130 by a securing means 115. It should be observed that in FIGURE 2, only one of a pair of earmuffs interconnected by connecting band 130 is shown.

The acoustic earmuff 100 comprises a rigid earcup 111 and a one-piece foam cushion 112. Earcup 111 has an inward protrusion 117 at the opening in the cup and foam earmuff cushion 112 has an annular recess 118 for receiving the protrusion 117 in snap-in fashion.

The one-piece cushion 112 of the present invention should be lightweight, deform readily to the wearer's head contour, distribute clamping pressure evenly over the contact area, and maintain a substantially airtight seal even under conditions of rapid movement between the wearer's head and ear enclosure. The particular polymeric foam material employed in the fabrication of the one-piece cushion 112 will be dictated by considerations of economics, the specific mode of fabrication used, allergenicity and similar considerations. In view of the foregoing, the one-piece cushion 112 of the present invention may be composed of any suitable material known in the art, including but not limited to natural rubber, polyvinyl chloride, silicone rubber, EDPM rubber, polyisobutylene, polyethylene, polyamide, polyurethane, SBR

rubber, polybutadiene, ethylene vinyl acetate elastomer, acrylic elastomer, neoprene rubber, and the like.

A particularly preferred material is hydrophilic polyurethane foam having a fine cell structure and high flow resistance, such as the polyurethane foam compositions disclosed in U.S. Patent No. 4,158,087 to Louis L. Wood entitled "Urethane Foams Having Low Resiliency". The disclosure of the entire Wood patent is incorporated herein by reference.

Polyurethane foams are generally preferred for their formulation flexibility, easy molding characteristics and economics. Especially preferred are polyether polyurethane foam compositions due to the generally soft surface "hand" or feel to the skin when touched. These foams tend to contribute to the sense of comfort enjoyed by the wearer, and are typically derived from a polyoxyalkylene urethane prepolymer containing an aqueous synthetic polymer latex, such as styrene-butadiene or acrylic latex. Such prepolymers are readily water blown to a form-stable foam body in a suitable mold.

Preferred polyurethane foams also include those producing dynamically stiff cushions having a complex spring constant of at least about 300 pounds/inch and a material loss factor of at least about 0.25. Particularly preferred dynamically stiff foams have a complex spring constant of at least about 1000 pounds/inch. Such foams are described in U.S. Patent No. 5,420,381 to Gardner, incorporated herein by reference. Details of Transmissibility testing to determine the complex spring constant K^*, and the material loss factor, η, are discussed below.

In order to obtain these characteristics, the cushions may be formulated using di- and tri - functional polyether polyglycols of varying molecular weight. At least a portion of the polyol should have a functionality greater than 2.0 to maintain a foam with the defined characteristics. Other methods of formulating compositions which produce molded, dynamically stiff, noise excluding earmuff cushions include use of surfactant combinations to maintain closed or fine cell structure, a requirement for noise excluding earmuff cushions, adjusting the density of the foam, and underindexing.

Underindexing refers to the ratio of equivalents of isocyanate to the equivalents of hydroxyl. Any ratio of under 1.0 is underindexed, and a ratio of less than 0.9 preferred. Lowering of the isocyanate index (NCO/OH) results in softening as does increasing polyol chain segment length. Underindexing is not new to the art and was used in the early 1960's to produce soft foams for use in mattresses and the like as disclosed in U.S. Patent No. 3,377,296 and Cellular Plastics - Today's Technology, April 24-25, 1963, "Technology of Super Soft Flexible Urethane Foams" by Dwyer, Kaplan, Pirer and Stone. The disclosure of these entire documents are herein incorporated by reference.

Referring still to FIGURES 2 and 6, the rigid earcup 111 can be formed from any suitable plastic material or the like. Preferred materials are high-impact resistant thermoplastics such as polyvinyl chloride, ABS resin, glass-filled polypropylene and other rigid, high density polymers. Similarly, the connecting band 130 is composed of any suitable material that provides the resilience when the open end of the "U" is splayed apart to fit the earmuff device to the head of a user. The recovery forces generated in the strained connecting band thereafter serve to bias the earmuffs inwardly, thus fostering a secure attachment and good acoustical sealing of the earmuff(s) 100 to the user's head. Suitable materials of construction for the connecting band 130 includes various thermoplastic or metallic materials with high spring and low creep properties. Preferred thermoplastic materials include acetal, nylon, polyester, and the like.

FIGURES 2 and 6 further show the flexible headband 130 and suitable means of attachment 115. Attachment 115 consists of a post 119 comprising a shaft 120 and an expanded free end portion 121 of greater dimension than the shaft portion 120. The post 119 is centrally located on backwall 122 of the earcup 111. The expanded free portion 121 of post 119 can take any geometric form including, but not limited to, a sphere or ball. The post 119 is firmly affixed to the back wall 122 of earcup 111 and is directed outward therefrom. Although any means of connecting the earcup to the flexible headband is feasible, preferably the post 119 is molded to the earcup 111

during the fabrication process to yield an earcup with securing means in a one piece unit, thereby keeping a simple construction.

The connecting band 130 is constructed employing conventional techniques well known to those of ordinary skill in the art. The connecting band 130 may also be of such construction as to provide the capability for adjustment of its overall length. Such adjustable length resilient connecting band constructions are also known in the art.

In the preferred embodiment, as depicted in FIGURE 6 hereof, the band comprises a series of alternating open notches 136 and flat sections 137 at the open end portions of the generally "U-shaped" connecting band 113. The series of notches 136, preferably circular in shape, allows the earmuff 100 to be adjusted to the particular wearer. The flat sections 137 between the notches are inwardly facing undersized portions that provide resistance to the securing means 119, thereby maintaining the earcup 111 of the earmuff assembly at the desired connecting band length. The diameter of the notches 136 in the preferred embodiment will generally correspond to the preferred diameter of the shaft portion 120 of the post 119. Depending upon the width of the connecting band 130, a diameter of between about ¼ inch and ½ has been found to be suitable with a preferred notch 136 diameter of about ¼ inch.

In addition, it is preferred that parallel elongated slots 138 be employed adjacent to each side of the alternating series of notches 136 and flat sections 137. This allows for greater flexibility of the earmuff with the movement of the wearer's head. In general, the elongated slots 138 will be approximately 1/16th to approximately 1/8th of an inch in width. This width has been found suitable in providing the earmuffs 110 with the flexibility to permit omni-directional rotation. The preferred embodiment of the connecting band 130 with alternating notches and flat sections, as well as the elongated slots, therefore allows the earmuff 100 to be "snapped" or "popped" into the connecting band 130 and remain seated in a particular notch at the desired wearer length.

Various other features associated with connecting bands are also contemplated. For example, the connecting band 130 will typically contain at least two grooved ribs

131 along the "U" of the band to reduce the overall weight of the band yet maintaining suitable stiffness to the band material. A lighter connecting band ultimately produces a more comfortable earmuff while decreasing fabrication cost. For this reason, a connecting band 130 with four ribs 131 is preferred.

FIGURES 2 and 3 further show the preferred snap-in embodiment of the novel earmuff 100 of the present invention, wherein earcup 111 has an inward protrusion 117 from the opening in the earcup and foam cushion 112 has an annular recess 118 for receiving the protrusion 117 in snap-in fashion. The height of the earcup protrusion 117 as shown in FIGURES 2 and 3 should be between about 1/16 inch and about 3/8 inch, although smaller heights may be functional. The depth of the cushion recess 118 as shown in FIGURES 2, 3, 5, 8, 11, 13, 15, and 17 should preferably match the height of the protrusion.

The shape of cushion 112 may be cylindrical, round or rectangular to fit the generally matching earcup 111 design in a reasonable manner. The cushion is quite flexible and may also be made to a shape requiring deformation to fit into the earcup. Thus, a circular cushion could be fabricated so as to fit a cylindrical earcup. Then, too, the recess 118 in the cushion may be formed by earcup protrusion 117 and need not necessarily exist prior to assembly. Likewise it should be understood that although the preferred protrusion 117 of the earcup 111 faces inward for performance purposes, a protrusion which faces outward (see, e.g., FIGURE 27) is even easier to produce and is contemplated as part of this invention. The open edge of the earmuff earcup may also be used for attachment of cushion 112 using adhesive.

FIGURE 3 shows a further preferred embodiment of the present invention, wherein foam cushion 112 is beveled, having the most forward portion 150 for contact with the wearer's head about the ear narrower than where the cushion portion 152 contacts the earcup. The rounded tip 154 of the beveled portion is on the inside of foam cushion so as to seat cushion 112 closer to the wearer's ear. Such a design provides for less resistance to irregularities in the contour of a wearer's head and fits closer to the ear yielding a more comfortable fit. This design also allows greater deflection due to bending. Foam-filled bladder cushions of the current art, in contrast,

require the foam to be open celled with a hole at either the inside or outside of the bladder thus allowing the entrapped air to escape and resulting in compression of the cushion.

FIGURES 4 and 5 show an embodiment of the novel foam earmuff cushion 112 of the present invention having an annular recess 118 for receiving a protrusion built into the earcup. The foam cushion of this embodiment has neither an attached acoustical liner nor a stiffer interface layer to facilitate the cushion being snapped-in (described in further detail below). FIGURES 7 and 8 show a preferred beveled foam earmuff cushion 112 having an annular recess 118 for receiving protrusion 117 built into the earcup. Again this embodiment has neither an attached acoustical liner nor a stiffer interface layer.

FIGURE 9 shows an assembled acoustic earmuff device consisting of a flexible headband 130 with two attached earmuffs 100 connected by suitable means 115, each earmuff 100 consisting of an earcup 111, cushion 112 and sound absorbing earmuff cup liner 114.

FIGURES 10 and 11 show yet another preferred embodiment of the foam earmuff cushion 112 of the present invention. In this embodiment, sound absorptive (acoustical) liner 114 forms a composite with cushion 112 at interface 123. Interface 123 may be a stiffer layer formed during the molding process if sufficient foam is placed into the mold. Alternatively, a film or thin sheet may be placed over the acoustical lining in the mold and attached during foam formation. The acoustical liner 114 may be of any practical thickness with a thickness of about 0.5 inch being preferred for most earmuff designs. The acoustical liner may be of any material having a porosity sufficient to absorb high frequency sound of about 1000 to about 8000 Hertz. Polyurethane open-celled acoustical foam is normally preferred because of its low cost and low density. FIGURES 12 and 13 are similar to FIGURES 10 and 11, showing a preferred beveled shape cushion 112 and acoustical liner 114 composite of the present invention having an stiffer interface layer 123. The scope of this invention includes foam cushion-acoustical liner composites that are not snap-in.

FIGURES 14 and 15 show a further preferred earmuff cushion 112 comprising a stiffer layer 123. Stiffer layer 123 may be formed by using sufficient foam during the molding process. Alternatively, this stiffer layer 123 may be formed by coating or adhering a film or thin sheet to the rear of the cushion as shown but is preferably attached during the foam cushion molding process, by being placed in the mold prior to foam formation. This relatively stiff interface layer is stiff enough to aid snap-in and retention to the earcup and soft enough to allow snap-in. The stiffness of the interface should be matched to the size protrusion by trial and error.

FIGURES 16 and 17 show another preferred beveled composite of cushion 112 with sound absorptive liner 114 with a stiffer interface layer 123. This is intended to show the variation which can occur in use of a beveled cushion construction. The primary purpose of the beveled cushion is to fit to the wearer's head close to the ear. The bevel design can also be shaped to give optimum desired results with the stiffness of cushion material selected.

Since omission of a cushion seal plate tends to reduce low frequency performance, preferred embodiments of the present invention include new cushion shapes and materials to optimize performance while still minimizing the total number of components. FIGURES 18 though 27 are cross sections of other contemplated molded foam cushion shapes and types of attachment to an earcup.

FIGURE 18 shows a fairly standard square to rectangular cross-sectional shape.

FIGURE 19 shows the preferred curved, beveled, cross-sectional shape. This design allows for tucking the wearer's ear inside the inward tip, and fits very close to the ear. The most forward portion of the cushion intended for contact with the wearer's head about the ear is narrower than the thickest part of the cushion.

FIGURE 20 is of a sloped, beveled, cross-sectional shape, which works well for cushions which are softer and tend to compress more. There is also a tendency for this style cushion to fold inward somewhat. This style also fits close to the wearer's ear.

FIGURE 21 is of an inwardly curved, cross-sectional shape. With this design the thickness of the foam shape depends on the stiffness of the foam from which the

cushion is made. Although not beveled, this shape cushion works similarly to that shown in FIGURE 19, having an inward tip.

FIGURE 22 is of a modified outward taper cross-sectional shape and combines the features of ability to tuck in the wearer's ear inside the inward tip, with increased contact area with the head. Increased contact area with the head often leads to a performance advantage when using dynamically stiff cushions. This is because once the cushion is of a certain dynamic stiffness the flesh becomes the softer spring on which the cushion moves in a pumping motion at lower frequencies. By increasing the contact with the flesh, the flesh involved has a higher spring constant thus helping to reduce the motion of the earcup.

FIGURE 23 is similar to FIGURE 22, further having an overhang portion 158 of the molded foam cushion overlapping the outer side of the earcup opposite the earcup protrusion for greater cushion retention. This overhang 158 is also shown in FIGURES 24-26.

FIGURE 24 is similar to FIGURE 23, further having a forward raised inward tip 160 for contact about the ear close to the ear, thereby ensuring more positive closure while maintaining increased contact with the head. As with its two predecessors, this shape allows for tucking in the ear. This FIGURE 24 also shows a widening 162 of the cross-section of the forward portion of the earcup supporting the protrusion 117, as well as a longer protrusion 117. Both the widening 162 and the longer protrusion 117 add to the support of the cushion, which may further enhance cushion dynamic stiffness.

FIGURE 25 shows a cushion having a generally sloping, outward taper cross-section shape, using a wider than normal earcup edge as the retaining protrusion. The outward bevel of the outer earcup edge, the recess that the foam cushion protrusion fits into, and potential use of adhesive all aid in retention as does the force against the cushion when worn.

FIGURE 26 shows a cushion of similar shape to that of FIGURE 24, having a raised inward tip, but fitting a normal earcup edge. Increased overhang 158 overlaps the outer earcup edge and aids in cushion retention. The support given by the attached

acoustical liner 114 helps support the cushion during use and also aids in retention. A stiffer layer at the cushion interface with the sound absorbing liner may also add stiffness to the cushion and help aid in cushion retention. With cushion-acoustical liner composites, other means of attachment using the acoustical liner to adhesively or mechanically bond the composite to the earcup may be employed, and still remain within the scope of the invention.

FIGURE 27 shows an earmuff cushion with a raised inward tip having an annular recess for accepting an outward protrusion 180 at the outer edge of the earmuff earcup. Here the cushion 112 is attached to the acoustical foam liner 114 at interface layer 123. As alluded to earlier, an earcup with an outward facing protrusion is easier to mold or form. The higher the protrusion, the easier it is to mold, with a protrusion of about 1/8th inch being relatively easy to produce. An earcup with inward protrusion requires a more complex mold.

The above discussion mentions tucking the wearer's ear behind the cushion as a positive element to the performance of a hearing protector. Normal cushions such as the shape shown in FIGURE 1 are usually designed to the 95th percentile wearer. That is to say, based on the statistics for ear size, an earmuff is usually designed with cushions having an ear-receiving hole large enough for 95% of all ears to fit into. In most cases earmuff performance could be enhanced by designing a smaller hole, but with the resulting disadvantage that such a hearing protective device would not fit an adequate portion of the population. An earmuff design such as that of FIGURES 19, and 21 through 27, wherein the tip of the cushion is on the inside of the cushion, allows greater latitude in designing a smaller earmuff with greater potential for performance optimization. As shown particularly in these FIGURES 19, and 21-27, the cushions comprises an inward tip portion having a lesser perimeter than that of the hole in the earcup, the inward portion being of a shape so as to allow a portion of the pinna to be tucked thereunder.

For stiffer cushions, the modified reverse taper designs of FIGURES 22 through 26 increase performance as the outward foam contacting the head does not appear to act as part of the earcup for the purpose of catching sound.

Any or all of the elements of these FIGURES may be combined for the practice of this invention along with elements made obvious by the inclusion thereof.

In an alternative embodiment of the present invention, there is provided a process for joining an open-celled sound absorptive (acoustical) liner to the molded cushion during the molding process. The open-celled acoustical liner facilitates venting from within the mold through the open-celled liner during molding. Accordingly, an acoustical liner is placed in a mold such as that shown in FIGURE 31. Foam precursor is then injected into the mold, and the foam rises to form a cushion. Upon contact of the rising foam cushion with the acoustical liner during the joining process, a stiffer interface layer may form. This stiffer interface layer aids in the snap-in and retention of the molded foam cushion into the earmuff cup. Alternatively, a thin film or sheet may be placed on the acoustical liner in the mold, and be attached upon contact of the rising foam during cushion formation.

In yet another embodiment of the process of the present invention, as shown in FIGURE 31A,, mold top 203 and sides 202 are replaced with an earcup, i.e., the acoustical liner is placed directly into the earcup and the liner/earcup are used as the top of the mold. The foam precursor is injected as before, and forms an integrated one-piece unit of earcup, acoustical liner and foam component. A stiffer layer may also form or be attached between the acoustical liner and the foam component as described above. The one-piece molded foam cushion-liner composite may still be removed by the wearer and replaced if desired.

Cushions of the desired shape can be dipped, sprayed, or coated for increased wear- and tear-resistance. A preferred coating is referred to as "mold coating" and consists of spraying a coating composition, typically polyurethane, into the mold. The foam later rises and the cushion is removed from the mold coated. Other coating materials such as silicones and various latexes of polyvinyl chloride, polyurethane, polychloroprene (neoprene rubber) are also suitable.

The process and earmuff with an incorporated foam cushion-acoustical liner composite of the present invention provides an earmuff assembly which overcomes the problem of earcup assemblies of the prior art. The present invention combines

traditional muff parts, i.e., cushion, sealplate and muff liner into a one-piece unitary cushion insert. The resulting cushion-liner composite provides for a simpler and cost effective acoustic earmuff device, such device comprising only three pieces (foam cushion, connecting band and earcup) as opposed to traditional assemblies comprising six to eight parts and involving welding and other sub-assembly steps. In addition, the cushion of the present invention easily snaps onto the earcup without the aid of mechanical or chemical bonding techniques. The cushion is readily disposable when soiled and easily removable due to its insertable nature. Similarly, the cushion may be removed when different wearers are using the same earmuff device.

The present invention is further illustrated by the following non-limiting examples.

EXAMPLE 1

A foam cushion in accordance with the invention was produced by foaming and polymerizing, in a mold, an aqueous phase polyether polyurethane foam precursor composition containing a self-crosslinking, acrylic latex modifier in accordance with U.S. Patent No. 4,158,087. A two-piece male/female mold was employed to form all external surfaces. A male plug was used to mold all internal surfaces. The finished foam cushion was removed from the mold, placed in a fabric bag, and dried in a clothes dryer set at a "medium" cycle to remove excess water from the cushion and to complete curing of the cushion.

The particular polyether polyurethane foam precursor composition was formulated as follows:

Component (Source)	Function	Parts by Weight
UCAR® 154 acrylic latex (Union Carbide Corp., Danbury, CT)	Acrylic polymer and reactant	33.52
Deionized Water	Reactant	46.31
Superfine Superfloss (Manville, Denver, CO)	Filler	15.50
PLURONIC® F-68 block-polymer solution (BASF Corp., Parissipany, NJ)	Surfactant	2.00
PLURONIC® 25R2 block-polymer (BASF Corp., Parissipany, NJ)	Surfactant	0.80
Orange Colorant (Sun Chemical Co., Fort Lee, NJ)	Colorant	1.00

The above formulation was then mixed with HYPOL® 2002 polyether polyurethane prepolymer (W.R. Grace & Co., Organic Chemical Division, Lexington, MA) in the ratio of 1 to 1 by weight.

The cushion was produced as a cushion-acoustical liner composite, with a shape and design substantially in accordance with the embodiment of the invention shown in FIGURE 21. An earcup resembling that shown in FIGURE 3 and a generally U-shaped headband similar to those shown in FIGURES 3, 6 and 9 was used. The earmuff device produced therefrom had the following characteristics:

Cushion

Height	3.95 inch
Width	3.38 inch
Opening:	
Height	2.13 inch
Width	1.65 inch
Thickness:	
Acoustical liner foam (Aresto 2)	0.50 inch
Cushion	0.38 inch
Recess depth	0.12 inch
Recess width	0.12 inch

Earcup

Post length 140	0.5 inch
Diameter:	
Free end portion	0.375 inch
Shaft portion	0.25 inch
Back wall thickness	0.125 inch
Material of construction	PVC

Connecting Band

Width Elongated slots	0.0313 inch
Length Elongated slots	2.00 inch
Diameter of notches	0.30 inch
Width across flat sections	0.25 inch
Number of ribs	4
Material of construction	Nylon

The earmuff of Example 1, composed on only three parts, adjusted itself well to the contours about the head, was comfortable and reduced noise reaching the ears remarkably well.

EXAMPLE 2

An earmuff device in accordance with the invention was produced using a foam precursor composition formulated as follows:

Component (Source)	Function	Parts by Weight	Equivalent Weight
Arcol LHT 240 (Arco Chemical)	Low MW Triol	56.00	234
Arcol PPG 425 (Arco Chemical)	Low MW Diol	12.00	210
Arcol LG 56 (Arco Chemical)	Med. MW Triol	12.00	1000
Y - 4327 (Union Carbide)	Surfactant	3.60	-
L - 45 (350) (Union Carbide)	Silicone Oil	3.60	-
1,4-Butanediol (GAF)	Chain Extender	1.50	45
DE83R (Great Lakes Chemical)	Fire Retardant	18.60	-
Antimony Oxide (Amspec Chemical)	Fire Retardant	6.20	-
Aluminum Trihydrate (Salem Industries)	Fire Retardant	40.00	-
Water	Blowing Agent	0.79	9
Methylene Chloride (Dow Chemical)	Blowing Agent	9.00	-
Tinuvin 765 (Ciba Geigy)	Stabilizer	0.60	-
Dabco T-12 (Air Products)	Catalyst	0.10	-
PPG 566 Green (Dayglo)	Colorant	0.90	-
Isonate 143L (Dow Chemical)	MDI Isocyanate	47.25	143

All components except the Isonate 143L were mixed, and then together with the Isonate 143L were run through an Edge Sweets mix/meter Foam Machine Model Flex-2H at a ratio of 3.49 to 1.00 respectively (Isocyanate Index = 0.759) and therein mixed and shot into a preheated mold at a temperature sufficient to cause foaming, about 50°C. FIGURES 30 and 31 show a typical mold 199 for use with the present invention, comprising a base 200, an insert 201, a retainer 202, a cover 203, and optional vents 204 (which were not used here). The acoustical foam liner 114 is shown bonded to the molded foam cushion 112 within mold 199.

The cushion was produced as a cushion-acoustical liner composite, with a shape and design substantially in accordance with the embodiment of the invention shown in FIGURES 16 and 17. An earcup resembling that shown in FIGURE 3 and a generally U-shaped headband similar to those shown in FIGURES 3, 6 and 9 was used. The earmuff device had the following characteristics:

Cushion

Height	3.85 inch
Width	3.30 inch
Opening:	
Height	2.70 inch
Width	2.15 inch
Thickness:	
Sound absorbing foam (Aresto 2)	0.50 inch
Cushion at contact with earcup	0.575 inch
Recess depth	0.125 inch
Recess width	0.125 inch

Earcup

Post length 140	0.5 inch
Diameter:	
Free end portion	0.375 inch
Shaft portion	0.25 inch
Back wall thickness	0.125 inch
Material of construction	PVC

Connecting Band

Width Elongated slots	0.0313 inch
Length Elongated slots	2.00 inch
Diameter of notches	0.30 inch
Width across flat sections	0.25 inch
Number of ribs	4
Material of construction	Nylon

Transmissibility Test Results:

Dynamic Complex Spring Constant; K^*	621 pounds/inch
Dynamic Material Loss Factor; η	0.90

The earmuff of Example 2, composed of only three parts, adjusted itself well to the contours about the head about the ear, was very comfortable and remarkably reduced noise reaching the ears.

TRANSMISSIBILITY TESTING

Transmissibility measurements are made using the fixture 5 shown in FIGURE 28 and the equipment described in the block diagram shown in FIGURE 29. Platform 15 used in this work was 5.0 inch (12.7 cm) diameter, 1.50 inch (3.81 cm) thick brass.

To ensure adequate contact 10 between the cushion and the platform 15, it was necessary to add weight so that a total weight of 1.00 pound (454 grams) was achieved. Weight was added using barium sulfate-filled epoxy resin within the earcup, or epoxy resin molded to the outside contour of the earcup with or without added steel . This total weight of 1.00 pounds was employed during all transmissibility tests. It is further important to ensure adequate stiffness of all connections and of the platform itself so as to give a straight line output free of secondary resonances up to at least 1000 Hz.

The test procedure was as follows:

The earcup with attached cushion and mass was placed on top of shaker platform 15. A transmissibility curve having the cursor at the natural frequency was obtained using an input level 20 of 0.2 G (acceleration of gravity, 32 feet/second/second). The natural frequency (fn) in Hz and the amplification (A) in dB was then read and recorded. FIGURE 32 shows transmissibility tracings for Examples 1 and 2 with the earcup being brought to 1.00 pound in weight by molding epoxy to the outside contour of the earcup. The Fn is directly related to the dynamic complex spring constant (K^*) of the cushion and the amplification at resonance (A, sometimes referred to as L_T) to the material loss factor. Since the K^* and $\hat{\eta}$ vary with frequency, the exact weight of 1.00 pound (454 gram) must be used to determine these values. K^* and $\hat{\eta}$ are calculated using the following equations:

$$K^* = (Fn/3.13)^2 \text{ W lbs./inch (W = weight in lbs.)}$$

$$= 1/\left((10^{L_T/20})^2 - 1\right)$$

where L_T = A = level of transmissibility at resonance (dB).

While preferred embodiments have been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the present invention has been described by way of illustrations and not limitation.

What is claimed is:

CLAIM 1. A molded foam cushion for incorporation with an earmuff device in snap-in fashion comprising a body with an edge for receiving at least one protrusion located at or near the edge of an earcup.

CLAIM 2. The molded foam cushion of claim 1 further comprising an annular recess located at the edge of the body, the recess being sized to receive the protrusion.

CLAIM 3. The molded foam cushion of claim 1 wherein the cushion comprises material selected from the group consisting of natural rubber, polyvinyl chloride, silicone rubber, EDPM rubber, polyisobutylene, polyethylene, polyamide, polyurethane, SBR rubber, polybutadiene, ethylene vinyl acetate elastomer, acrylic elastomer, neoprene rubber, and dynamically stiff foam.

CLAIM 4. The molded foam cushion of claim 1 wherein the cushion comprises dynamically stiff foam with a dynamic complex spring constant of at least about 300 pounds per inch and a material loss factor of at least about 0.25.

CLAIM 5. The molded foam cushion of claim 3 wherein the cushion further comprises a generally beveled shape with the most forward portion intended for contact with the wearer's head about the ear being narrower than the thickest part of the cushion.

CLAIM 6. The molded foam cushion of claim 1, wherein the cushion further comprises an inward tip, allowing the cushion to be seated closely about the wearer's ear.

CLAIM 7. The molded foam cushion of claim 6, wherein the inward tip is raised.

CLAIM 8. The molded foam cushion of claim 1, wherein the cushion further comprises an inward portion thereof having a lesser perimeter than that of the hole in the earcup, the inward portion being of a shape so as to allow a portion of the pinna to be tucked thereunder.

CLAIM 9. The molded foam cushion of claim 1 wherein the cushion further comprises an outward taper yielding a greater perimeter of contact with the head than the perimeter of the earcup.

CLAIM 10. The molded foam cushion of claim 1 wherein the cushion further comprises an attached stiffer layer at the rear, facilitating retention thereof.

CLAIM 11. The molded foam cushion of claim 1 wherein the outer perimeter of the cushion is greater than that of the earcup.

CLAIM 12. A composite component for incorporation into a hearing protective device comprising:

(a) a molded foam cushion; and

(b) an attached acoustic liner of sound absorbing material.

CLAIM 13. The composite component of claim 12 comprising material selected from the group consisting of natural rubber, polyvinyl chloride, silicone rubber, EDPM rubber, polyisobutylene, polyethylene, polyamide, polyurethane, SBR rubber, polybutadiene, ethylene vinyl acetate elastomer, acrylic elastomer, neoprene rubber, and dynamically stiff foam.

CLAIM 14. The composite component of claim 13 wherein the cushion further comprises dynamically stiff foam having a dynamic complex spring constant of at least 300 pounds/inch and a material loss factor of at least 0.25.

CLAIM 15. The composite component of claim 12 wherein the cushion further comprises an annular recess for receiving a protrusion located on the earcup of the hearing protective device.

CLAIM 16. The composite component of claim 12 wherein the cushion further comprises an inward portion thereof having a lesser perimeter than that of the hole in the earcup, of such shape so as to allow a portion of the pinna to be tucked thereunder.

CLAIM 17. The composite component of claim 12 wherein the cushion further comprises a generally beveled shape with the most forward portion intended for contact with the wearer's head about the ear being narrower than the thickest part of the cushion.

CLAIM 18. The composite component of claim 12 wherein the cushion further comprises an outward portion thereof having an outer perimeter greater than the outer perimeter of the earcup.

CLAIM 19. The composite component of claim 12 wherein the cushion further comprises an inward tip, allowing the cushion to be seated closely about the wearer's ear.

CLAIM 20. The molded foam cushion of claim 19, wherein the inward tip is raised.

CLAIM 21. An acoustic earmuff device comprising:

(a) a flexible connecting headband; and

(b) a pair of earmuffs, the earmuffs being fastened at opposite ends of the connecting headband and encompassing a wearer's ears to attenuate noise, wherein each earmuff comprises a rigid earcup with securing means and a molded foam cushion, the cushion having a central opening adapted to fit a wearer's ear, and being incorporated into the earcup in snap-in fashion.

CLAIM 22. The acoustic earmuff device of claim 21 wherein the cushion further comprises a stiffer layer at the rear of the cushion aiding in the retention of the cushion in said earcup.

CLAIM 23. The acoustic earmuff device of claim 21 wherein the cushion further comprises an annular recess for receiving a protrusion located at or near the edge of the earcup.

CLAIM 24. The acoustic earmuff device of claim 21 wherein the cushion further comprises material selected from the group consisting of natural rubber, polyvinyl chloride, silicone rubber, EDPM rubber, polyisobutylene, polyethylene, polyamide, polyurethane, SBR rubber, polybutadiene, ethylene vinyl acetate elastomer, acrylic elastomer, neoprene rubber, and dynamically stiff foam.

CLAIM 25. The acoustic earmuff device of claim 24 wherein the cushion further comprises dynamically stiff foam with a dynamic complex spring constant of at least about 300 pounds per inch and a material loss factor of at least about 0.25.

CLAIM 26. The molded foam cushion of claim 21 wherein the cushion further comprises a generally beveled shape with the most forward portion intended for contact with the wearer's head about the ear being narrower than the thickest part of the cushion.

CLAIM 27. The acoustic earmuff device of claim 21 wherein the cushion further comprises an inward tip, allowing the cushion to be seated closely about the wearer's ear.

CLAIM 28. The acoustic earmuff device of claim 27 wherein the inward tip is raised.

CLAIM 29. The acoustic earmuff device of claim 21 wherein the cushion further comprises an inward portion thereof having a lesser perimeter than that of the hole in the earcup, the inward portion being of a shape so as to allow a portion of the pinna to be tucked thereunder.

CLAIM 30. The acoustic earmuff device of claim 21 wherein the cushion further comprises an outward taper yielding a greater perimeter of contact with the head than the perimeter of the earcup.

CLAIM 31. The acoustic earmuff device of claim 21 wherein the outer perimeter of the cushion is greater than that of the earcup.

CLAIM 32. An acoustic earmuff device comprising:

(a) a flexible connecting headband; and

(b) a pair of earmuffs fastened at opposite ends of said connecting headband so as to encompass a wearer's ears, wherein each earmuff comprises a rigid earcup and a composite component comprising a molded foam cushion and an attached liner of sound absorbing material, said component being within the earcup.

CLAIM 33. The acoustic earmuff device of claim 32 wherein said molded foam cushion further comprises an annular recess for receiving a protrusion located at or near the edge of the earcup.

CLAIM 34. The acoustic earmuff device of claim 33 wherein said molded foam cushion further comprises material selected from the group consisting of natural rubber, polyvinyl chloride, silicone rubber, EDPM rubber, polyisobutylene, polyethylene, polyamide, polyurethane, SBR rubber, polybutadiene, ethylene vinyl acetate elastomer, acrylic elastomer, neoprene rubber, and dynamically stiff foam.

CLAIM 35. The acoustic earmuff device of claim 32 wherein said molded foam cushion further comprises dynamically stiff foam with a dynamic complex spring constant of at least about 300 pounds per inch and a material loss factor of at least about 0.25.

CLAIM 36. The acoustic earmuff device of claim 32 wherein said molded foam cushion further comprises a generally beveled shape with the most forward portion intended for contact with the wearer's head about the ear being narrower than the thickest part of the cushion.

CLAIM 37. The acoustic earmuff device of claim 32 wherein said molded foam cushion further comprises an inward tip, allowing the cushion to be seated closely about the wearer's ear.

CLAIM 38. The acoustic earmuff device of claim 37 wherein said tip is raised.

CLAIM 39. The acoustic earmuff device of claim 32 wherein said molded foam cushion further comprises an inward portion thereof having a lesser perimeter than that of the hole in the earcup, the inward portion being of a shape so as to allow a portion of the pinna to be tucked thereunder.

CLAIM 40. The acoustic earmuff device of claim 32 wherein said molded foam cushion further comprises an outward taper yielding a greater perimeter of contact with the head than the perimeter of the earcup.

CLAIM 41. The acoustic earmuff device of claim 32 wherein the outer perimeter of the cushion is greater than that of the earcup.

CLAIM 42. The acoustic earmuff device of claim 32, wherein the cushion further comprises an attached stiffer layer at the rear of the cushion aiding in the retention of the cushion in the earcup.

CLAIM 43. A cushion for an earmuff device comprising an raised inward tip, allowing the cushion to be seated closely about the wearer's ear,

CLAIM 44. A process for producing a composite earmuff cushion with an attached sound absorbing earcup liner wherein said liner is placed into the mold so that during foaming of the cushion the air may evacuate the mold cavity through or into the sound absorbing liner material and wherein the rising foam contacts said liner and bonds thereto.

CLAIM 45. The process of claim 33 wherein adequate foam material is placed into the mold so as to cause the formation of a stiff interface between said cushion, said liner being stiffer than either material in the final composite produce therefrom.

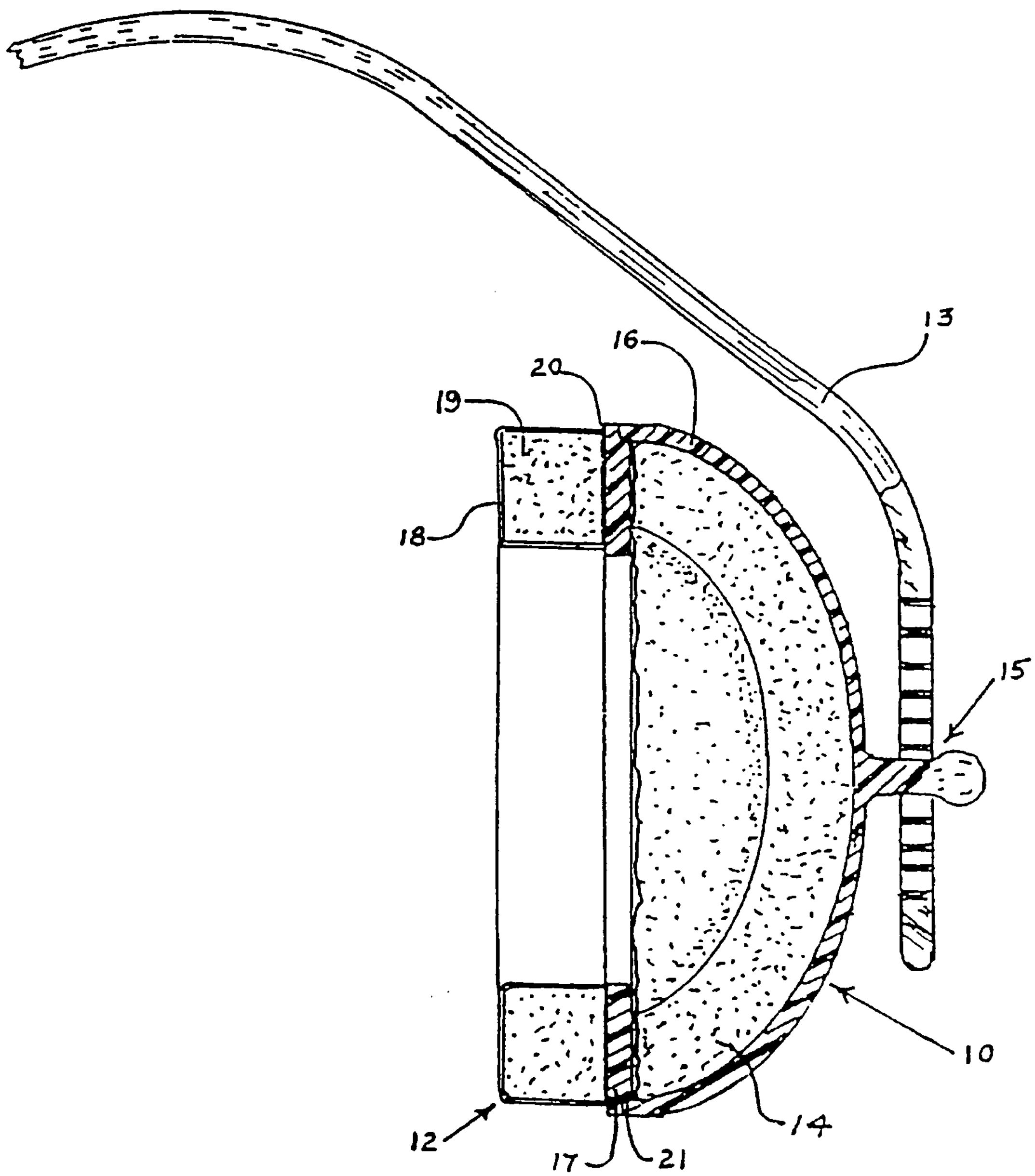


Fig. 1.

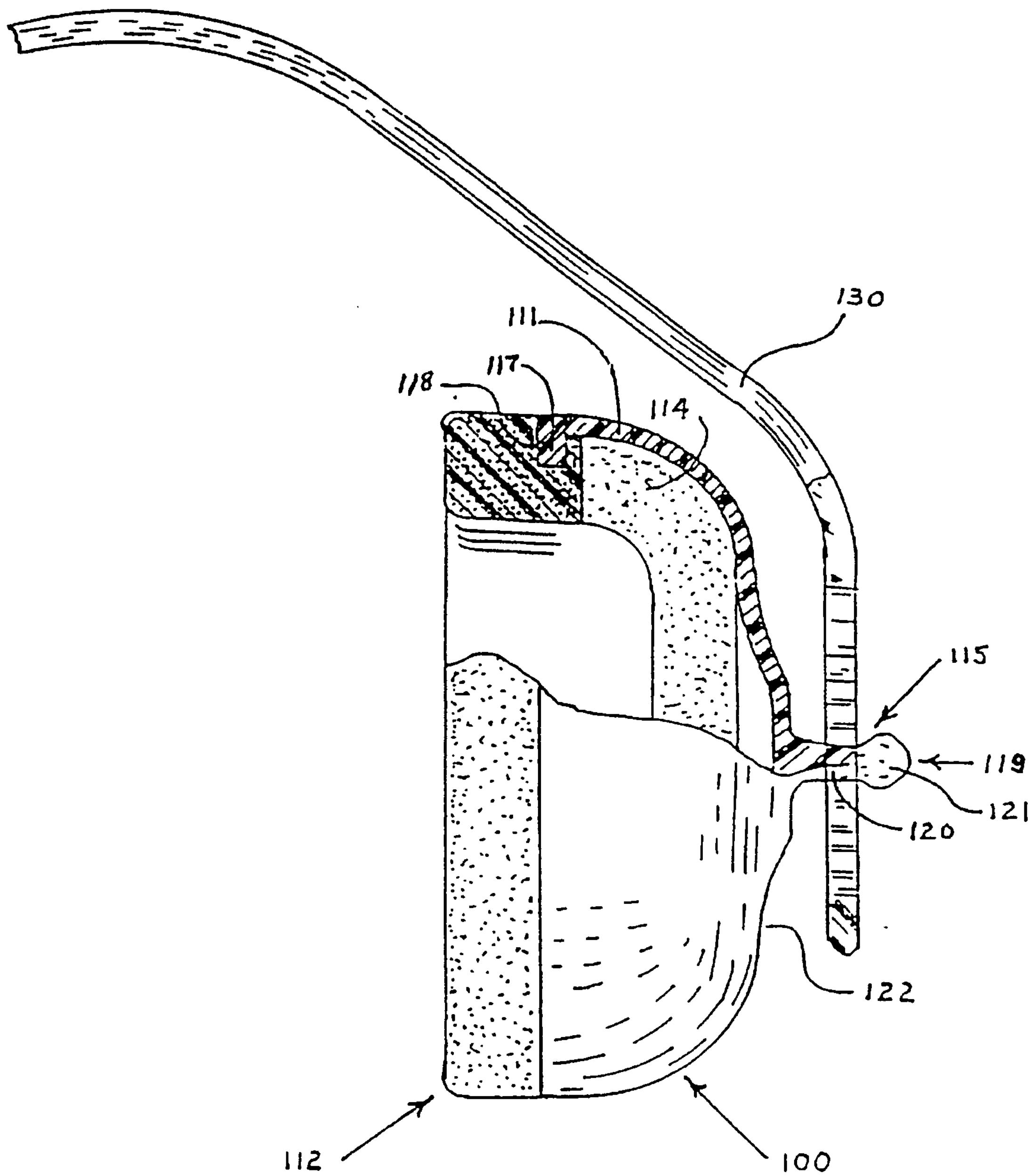


Fig. 2.

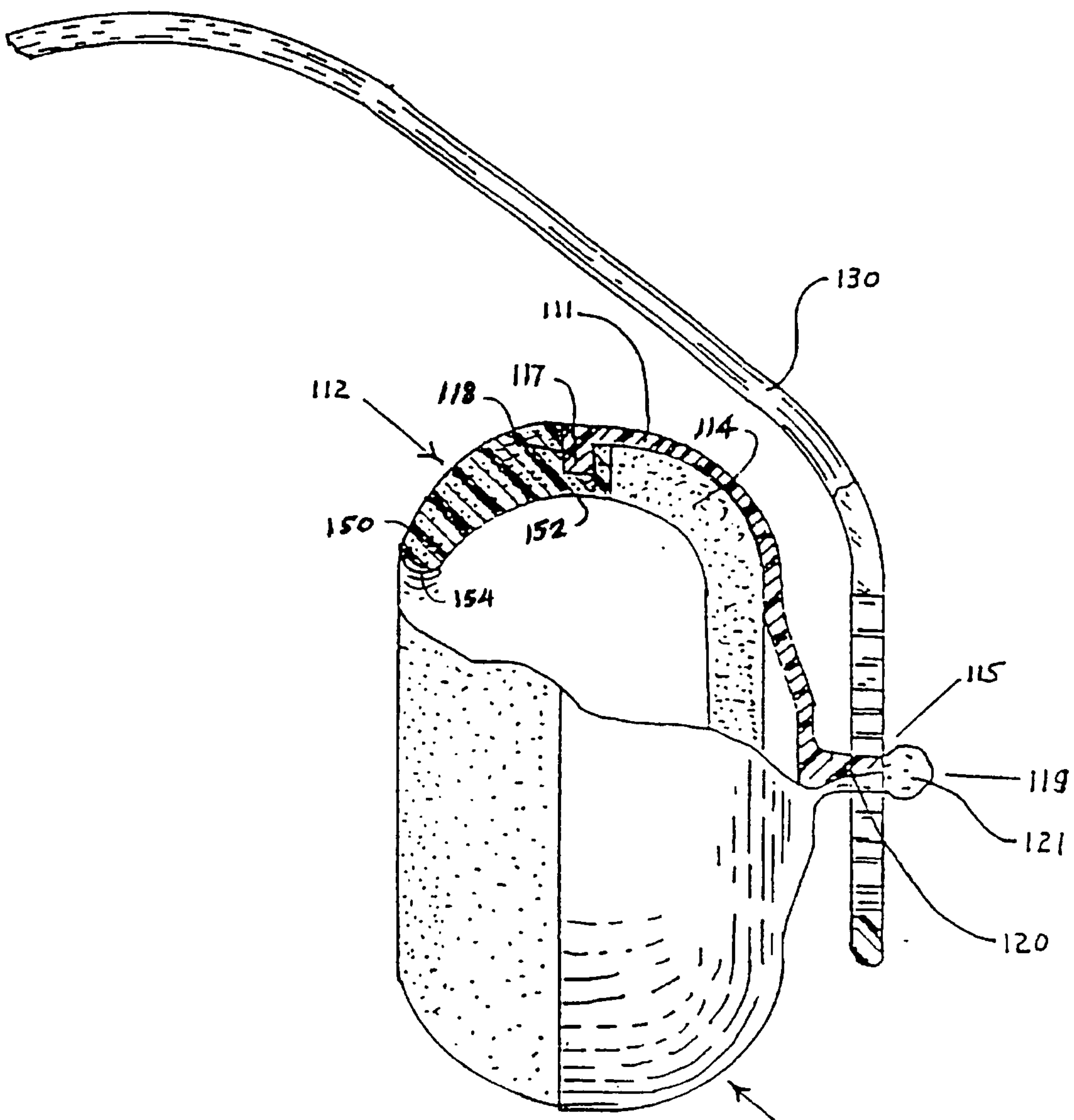


Fig. 3.

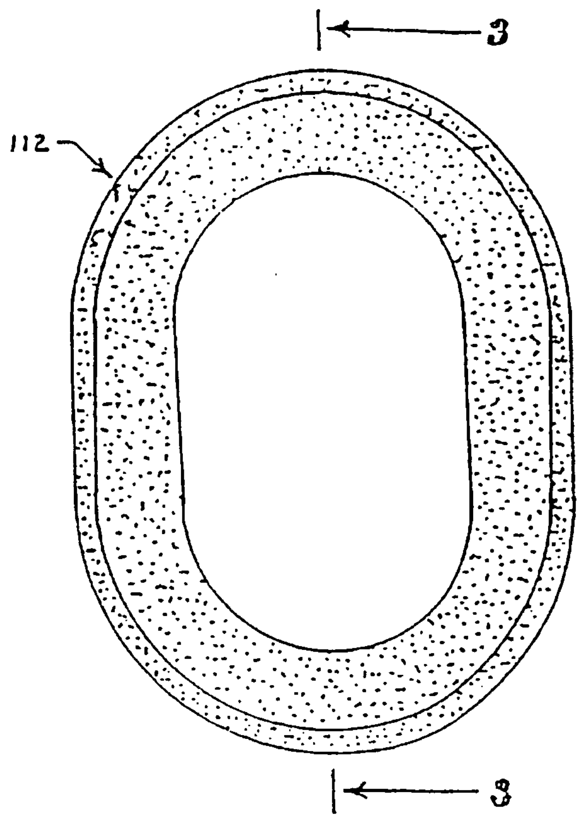


Fig. 4.

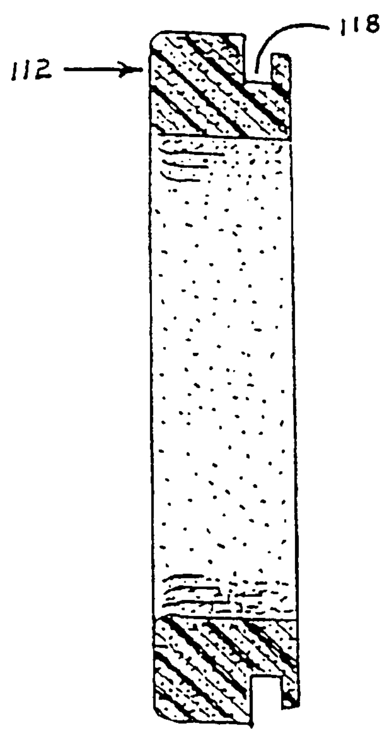


Fig. 5.

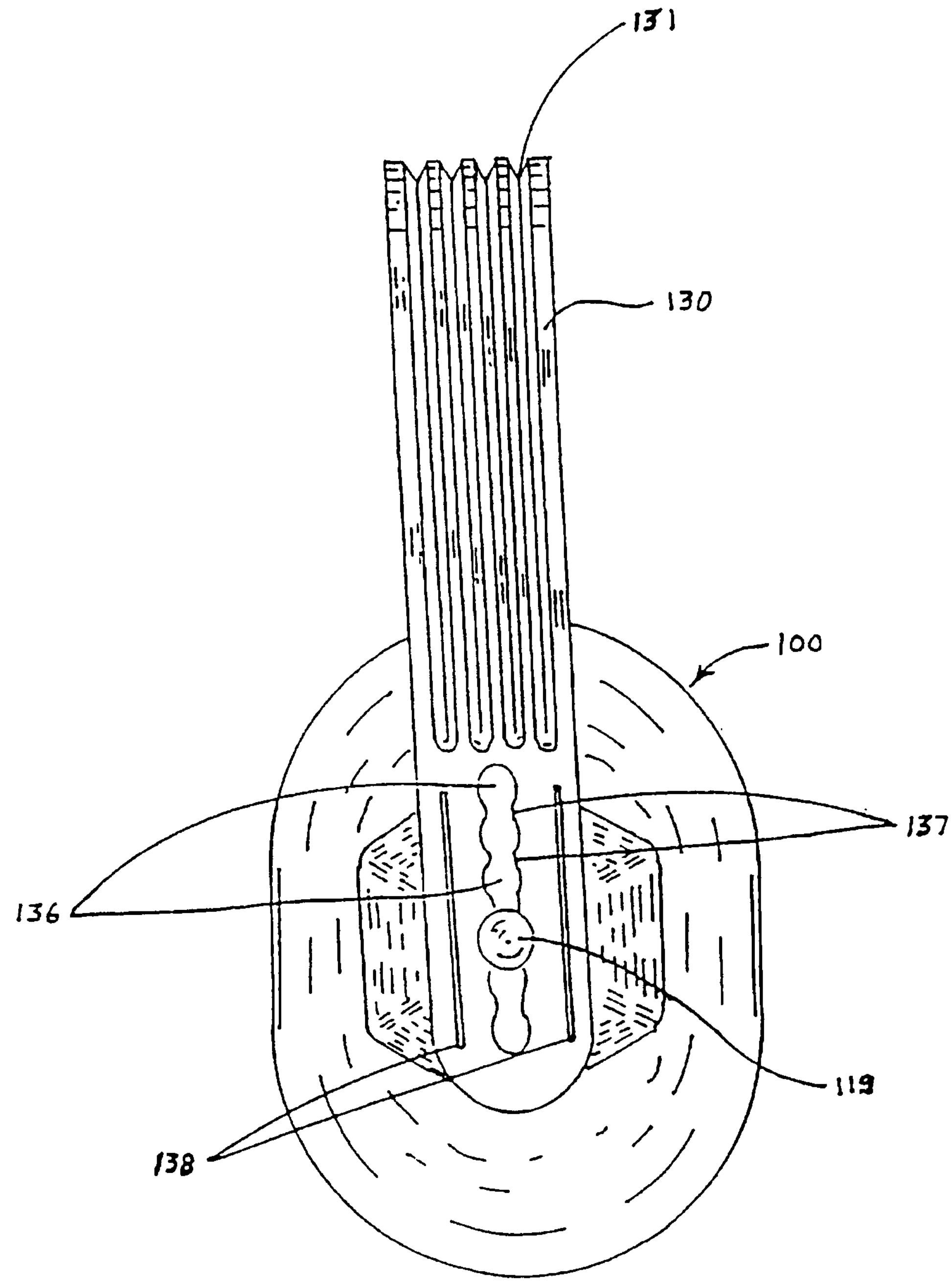


Fig. 6.

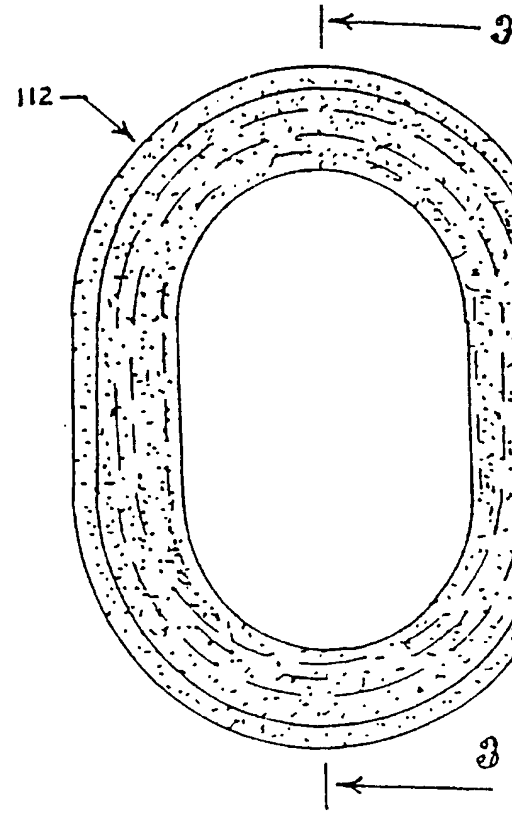


Fig. 7.

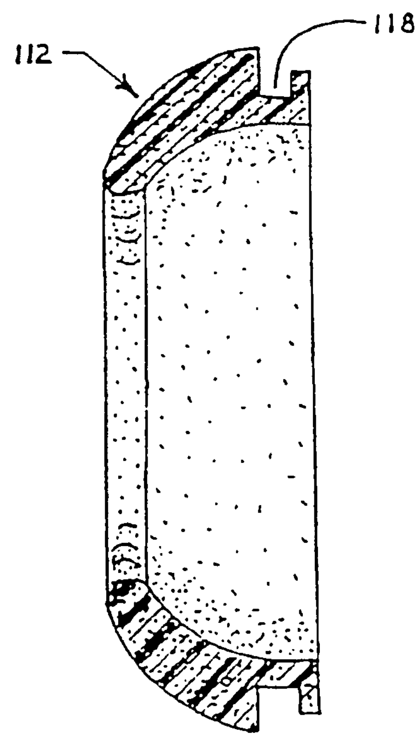


Fig. 8.

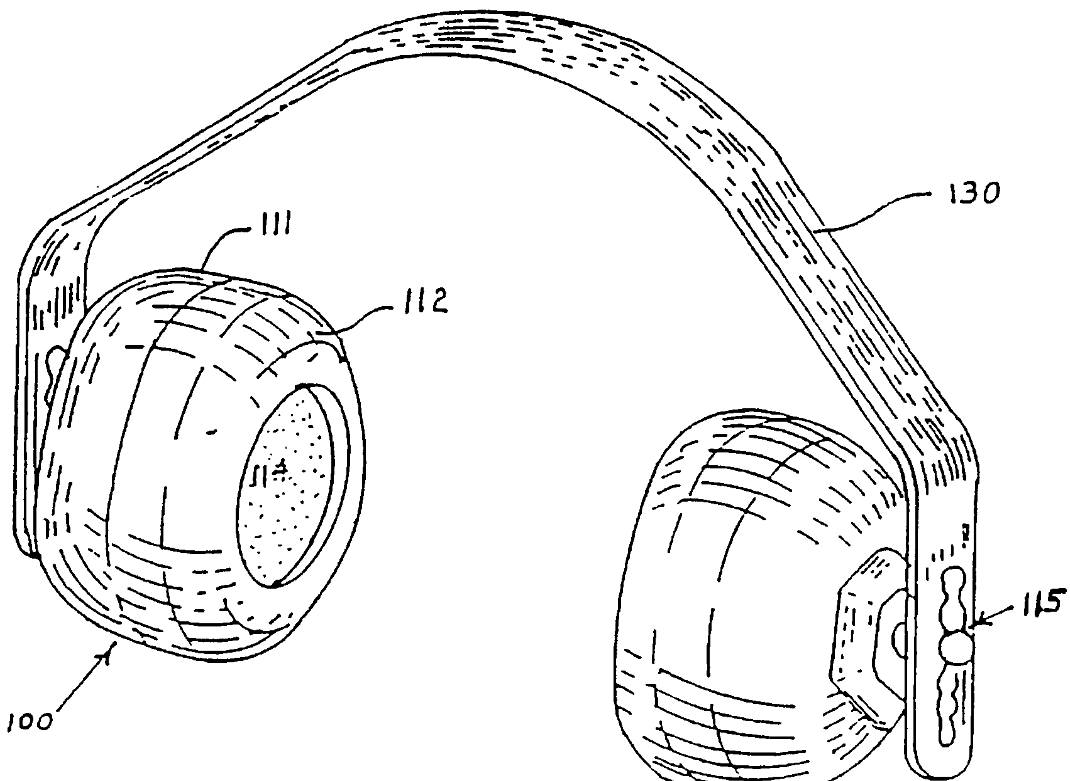


Fig. 9.

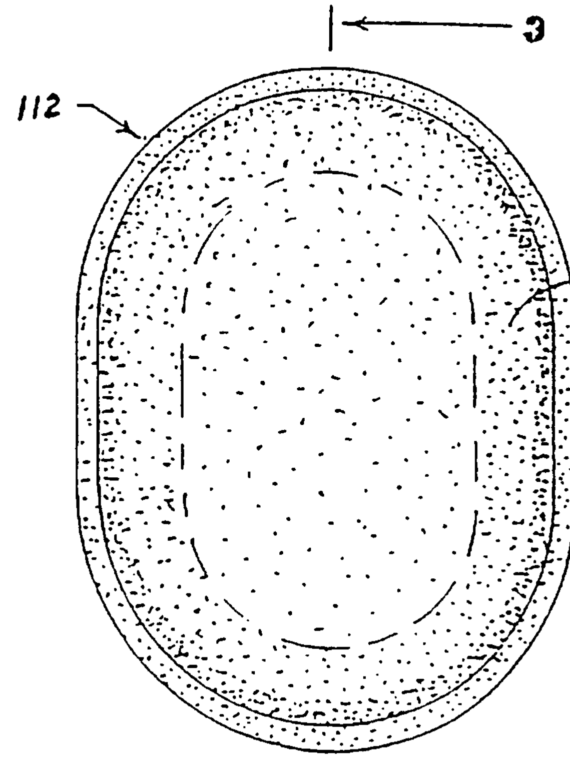


Fig. 10.

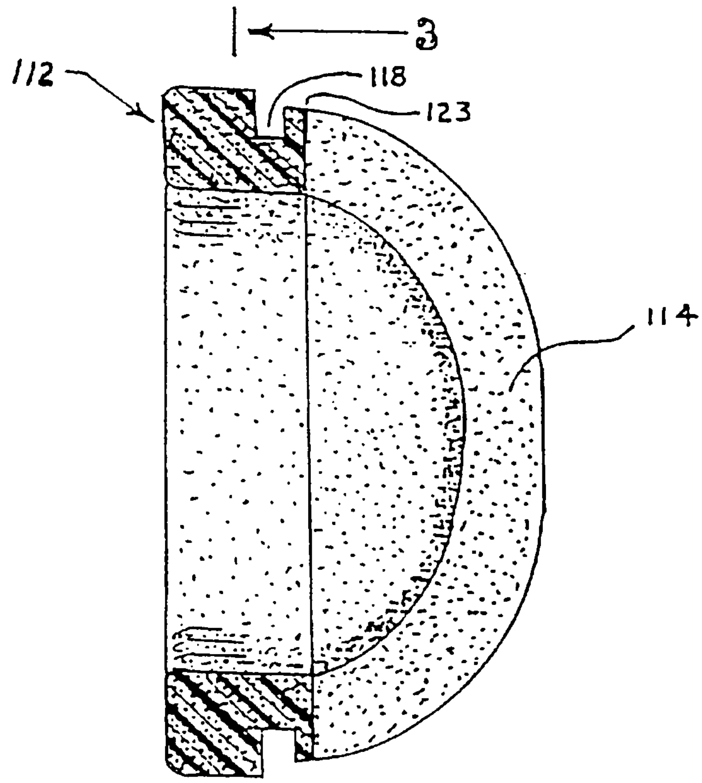


Fig. 11.

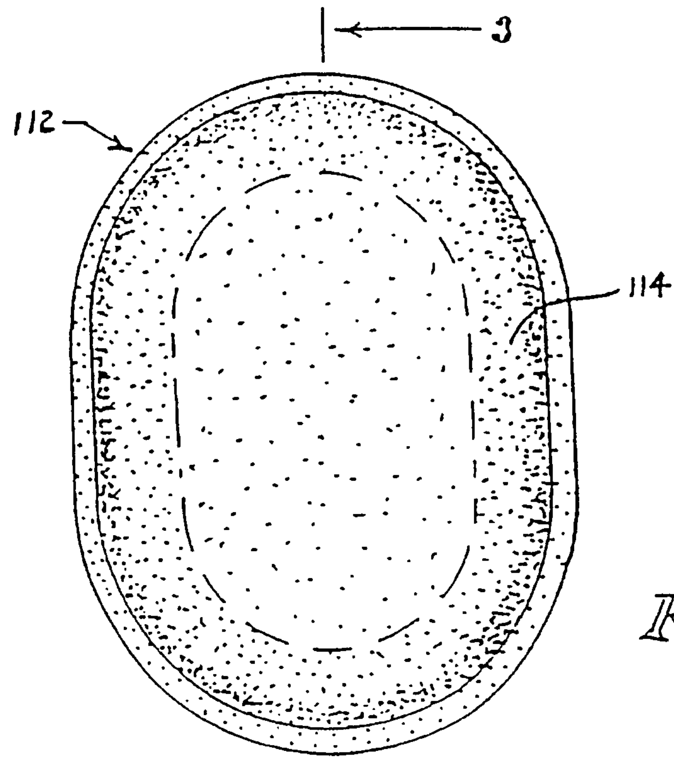


Fig. 12.

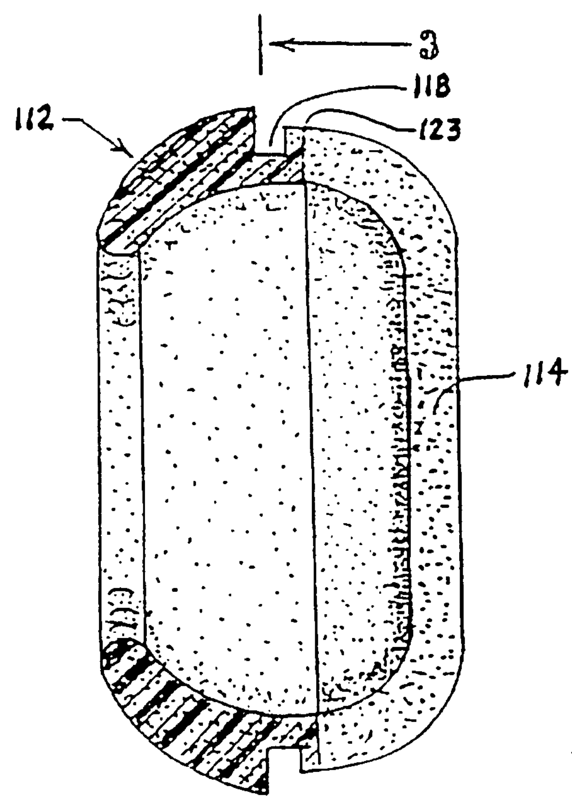


Fig. 13.

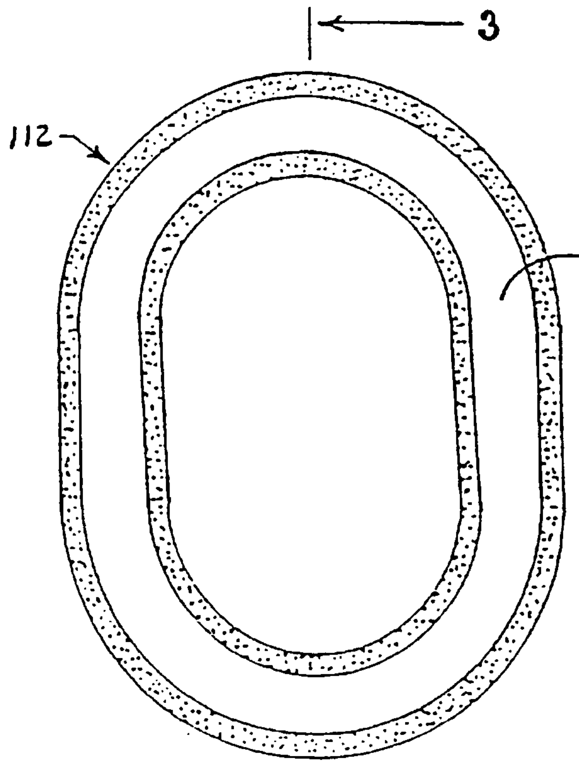


Fig. 14.

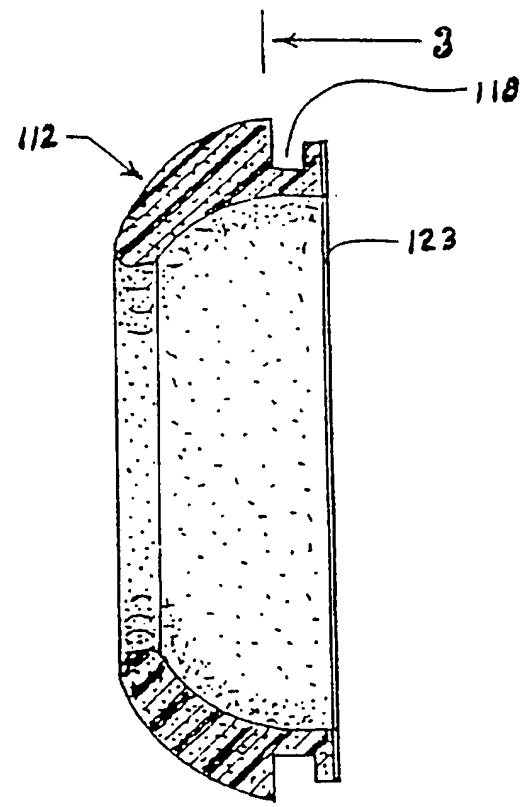


Fig. 15.

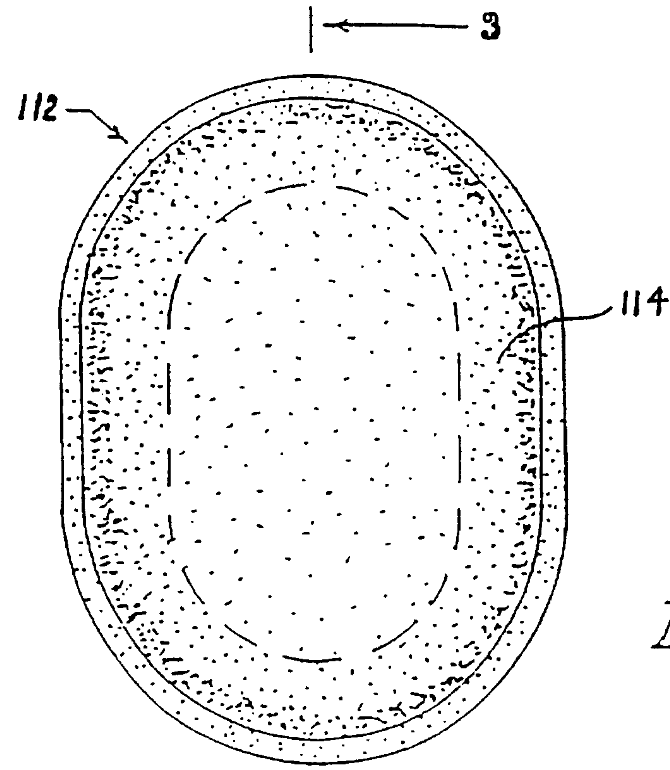


Fig. 16.

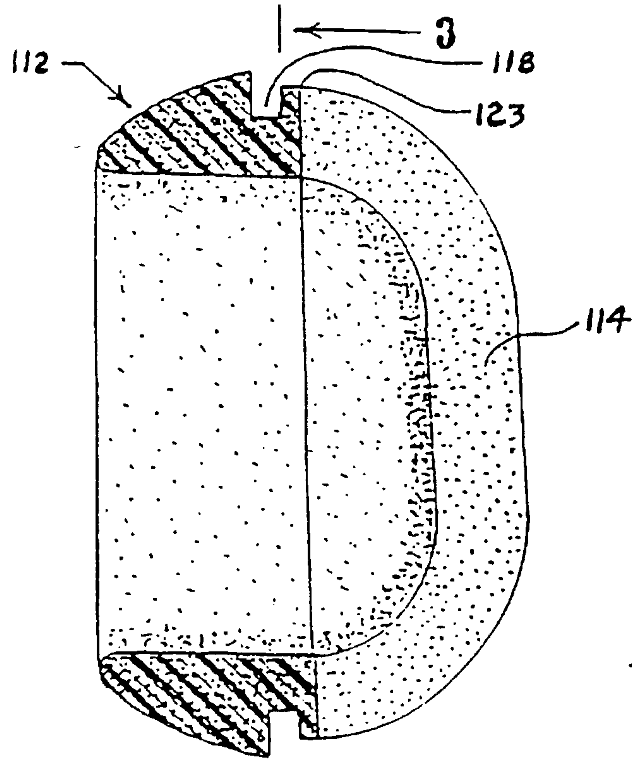


Fig. 17.

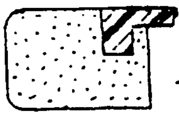


Fig. 18.

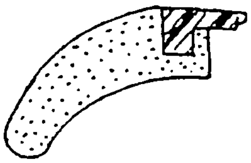


Fig. 19.

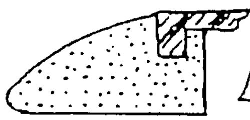


Fig. 20

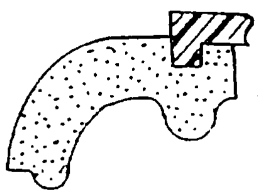


Fig. 21.

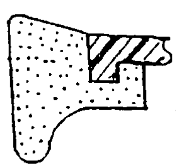


Fig. 22.

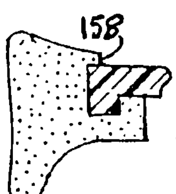


Fig. 23.

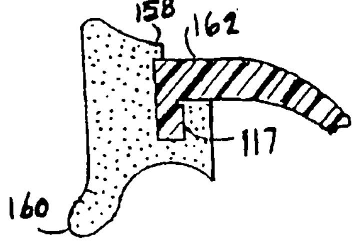


Fig. 24.

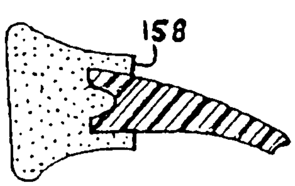


Fig. 25.

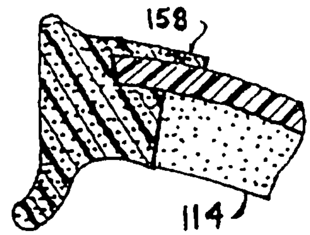


Fig. 26.

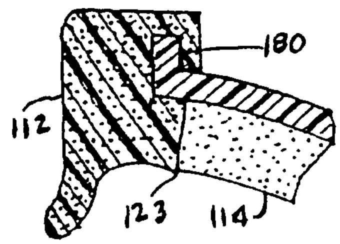
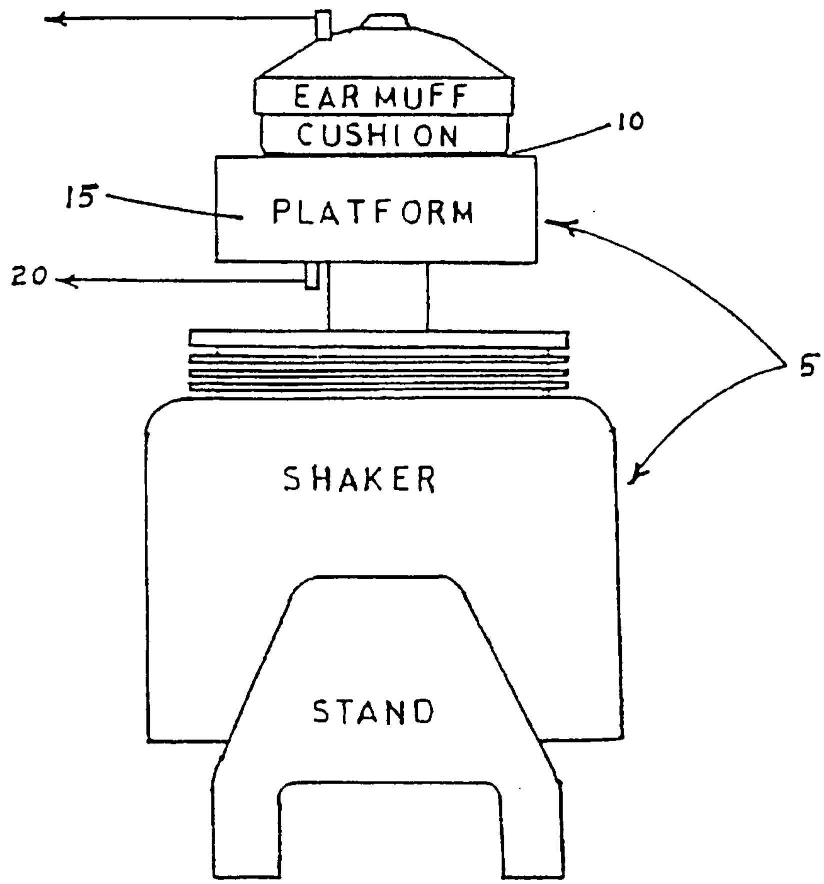


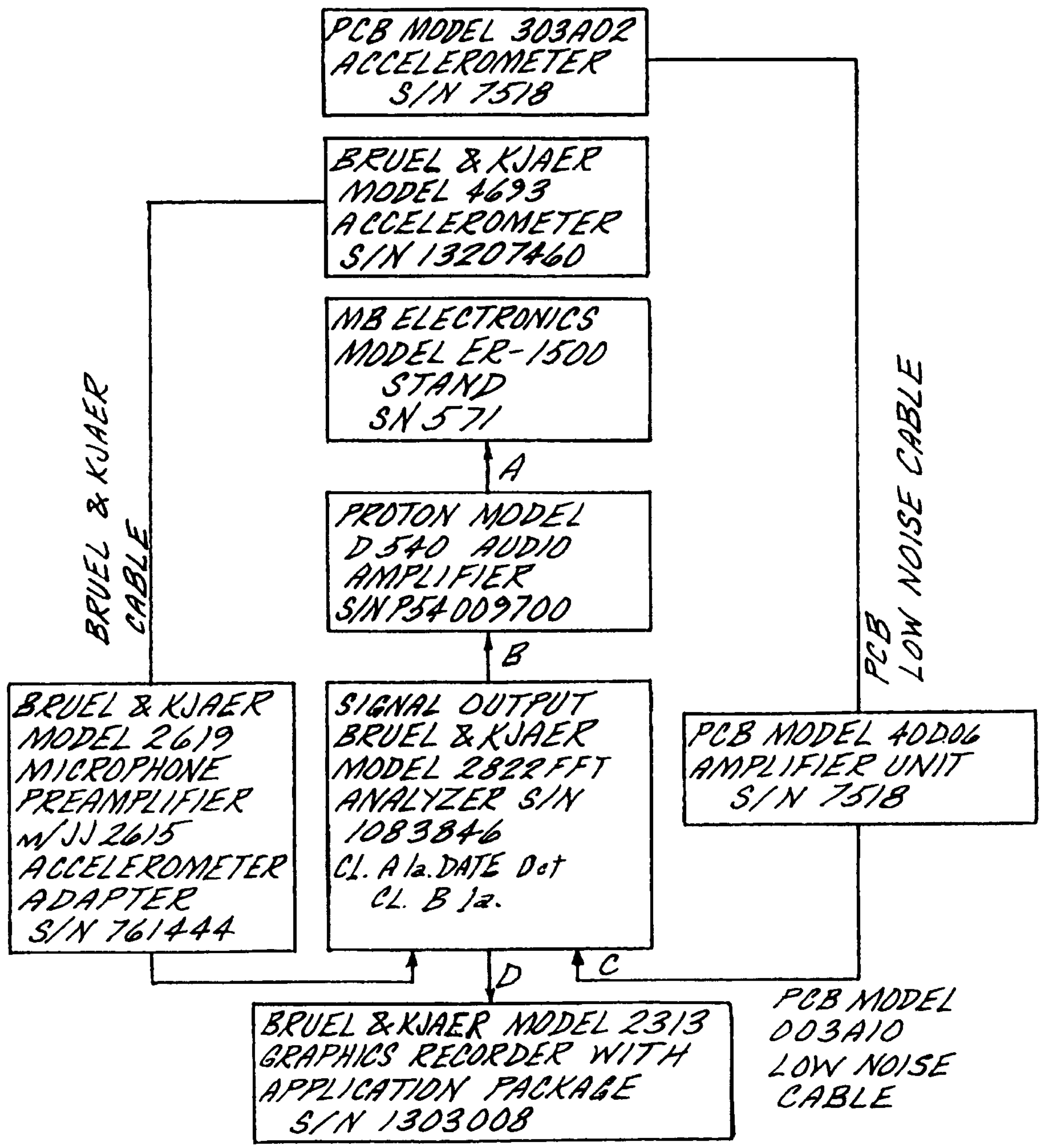
Fig. 27.

Fig. 28.

TRANSMISSIBILITY TEST FIXTURE



TRANSMISSIBILITY BLOCK DIAGRAM



(A) MB ELECTRONICS MODEL 935336 CABLE
(B) BELDEN RG58 C/U w/MALE RCA CONN. & MALE BNC CONN.
(C) FEMALE MICRO-DOT TO MALE BNC ADAPTER
(D) BRUEL & KJAER MODEL AO 1094 IEC 625 INTERFACE CABLE

Fig. 29.

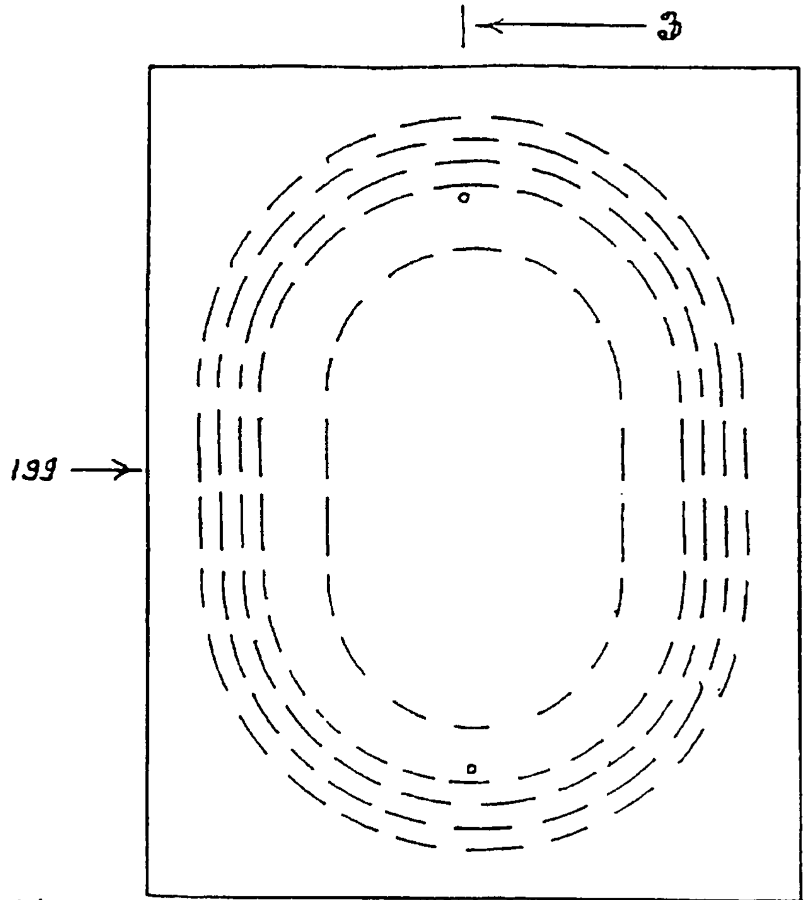


Fig. 30

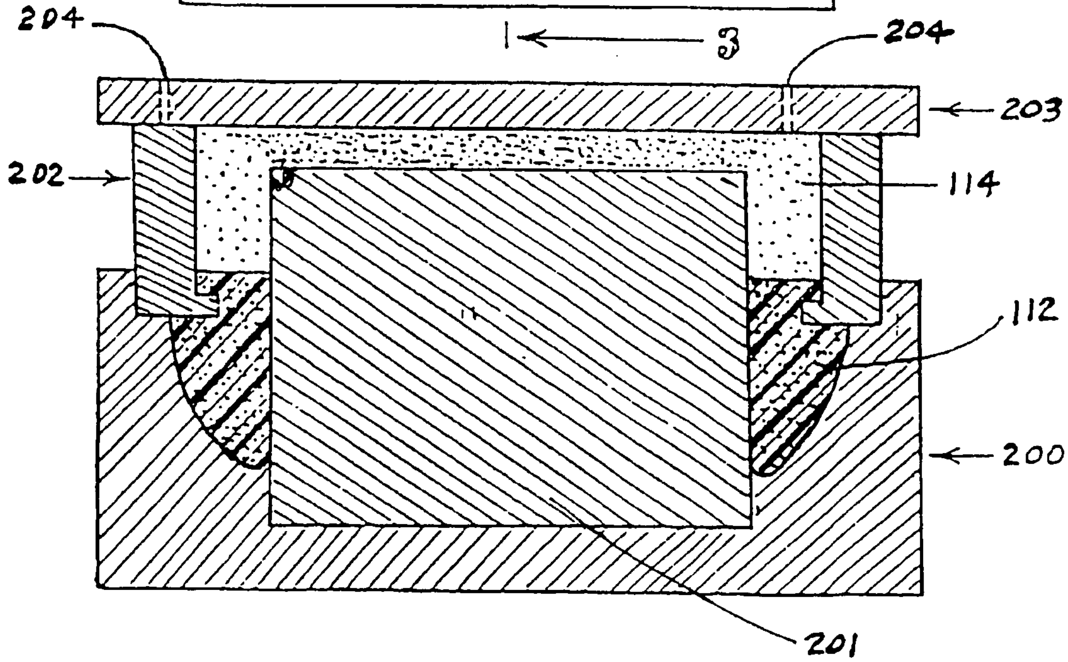


Fig. 31.

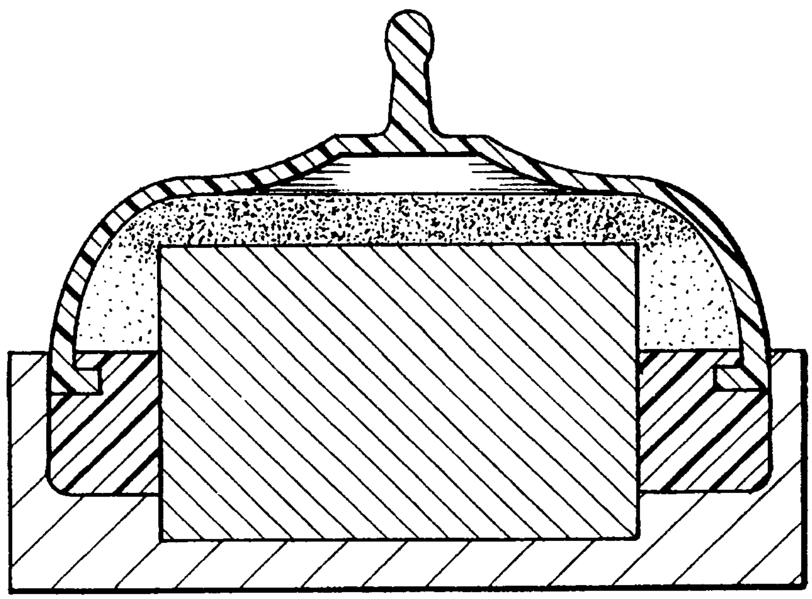
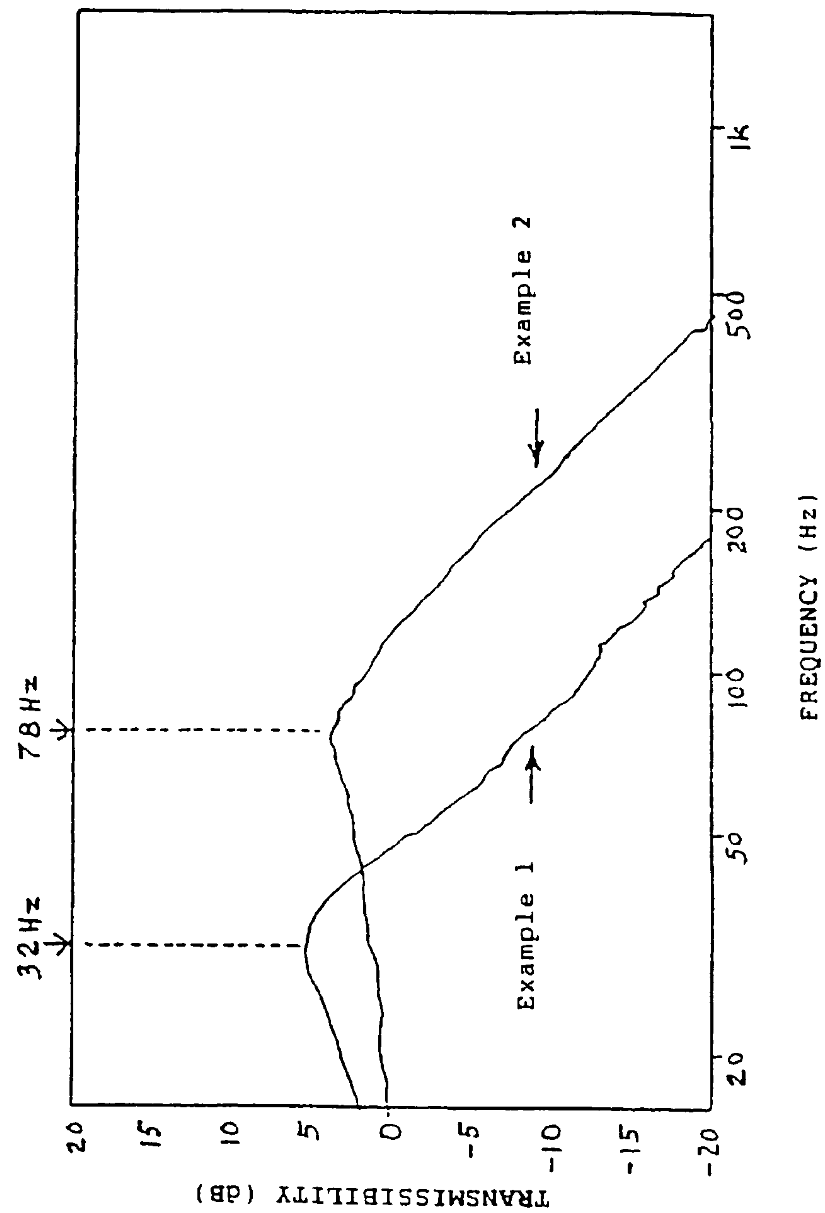


FIG. 31A

Fig. 32

TRANSMISSIBILITY TRACINGS FOR EXAMPLE 1 & EXAMPLE 2 CUSHIONS
EARMUFF CUPS BROUGHT TO 1.00 POUND WITH WEIGHTS
MOLDED TO OUTSIDE OF CUPS



INTERNATIONAL SEARCH REPORT	International application No. PCT/US97/09614

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A42B 1/06
US CL :2/209
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 2/209, 423; 181/129

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 3,051,961 A (CLARK) 04 September 1962, See entire document.	1-8, 11-21, 23-29, 31-39, 41, 43-45 ---------------- 9, 10, 22, 30, 40, 42
Y	US 3,593,341 A (AILEO) 20 July 1971, col. 4, lines 67-71.	9, 10, 22, 30, 40, 42
A	US 3,908,200 A (LUNDIN) 30 September 1975, See entire document.	1-43
A	US 5,023,955 A (MURPHY, II et al) 18 June 1991, See entire document.	1-43

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 JULY 1997	04 AUG 1997
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer LARRY D. WORRELL, JR. Telephone No. (703) 308-0861